STATE OF ALASKA

William A. Egan, Governor

Annual Progress Report for

EVALUATION OF SPORT FISH STOCKING ON THE KENAI PENINSULA-COOK INLET AREAS

by

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RESEARCH PROJECT SEGMENT

State: Alaska

Project No.: F-9-3 *Name:* Sport Fish Investigations of Alaska.

Study No.: G-II *Study Title:* Sport Fish Studies.

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Period Covered: July 1, 1970 to June 30, 1971.

ABSTRACT

Various aspects of the threespine stickleback's, Gasterosteus aculeatus, life history were studied in three Alaskan lakes. Data regarding population characteristics, depth distribution, duration of spawning, and incubation period are presented. The tolerance of threespine stickleback to rotenone and squoxin (1,1'-methylenedi-2-napthol) was tested in 48-hour assays. The minimum LC_{100} was 0.5 ppm 5% rotenone at temperatures varying from 54° - 68°F (12.2° - 20.0°C). For a thermal range of 57° - 61°F (13.9° - 16.1°C), the minimum LC_{100} was 0.5 ppm squoxin.

A shallow lake treated with 1.8 ppm 5% rotenone remained toxic to fish at all depths for about 40 days. Thereafter the rate of rotenone breakdown decreased with increased depth.

Growth and survival rates are compared for silver salmon, Oncorhynchus kisutch, red salmon, O. nerka, and rainbow trout, Salmo gairdneri, in various managed lakes. Transplanted Arctic grayling, Thymallus arcticus, were evaluated in four lakes.

Lake trout, Salvelinus namaycush, were re-introduced into Upper Summit Lake in an attempt to establish a self-sustaining population.

RECOMMENDATIONS

Retain present objectives of the study with emphasis directed toward the following:

1. Evaluate the survival and growth of rainbow trout in Musick and Stickleback lakes.

2. Continue the Upper Summit Lake lake trout transplant.

OBJECTIVES

1. To determine comparative survival and growth of stocked rainbow trout in lakes containing threespine stickleback and in waters where this species has been chemically controlled.

2. To investigate those aspects of the threespine stickleback's life history which relate to their control with fish toxicants.

3. To determine duration of toxicity in lakes which have been chemically treated to control threespine stickleback populations.

4. To determine the success of introduced grayling, lake trout, and red salmon (kokanee) in waters of the job area.

5. To provide recommendations for the management of stocked lakes and to direct the course of future studies.

TECHNIQUES USED

Stickleback collections from Johnson, Scout, and Bear lakes were made every Tuesday throughout the investigation. Plastic minnow traps, 16 3/4 inches in length, with 3/16-inch mesh were fished approximately 24 hours during each sample day. Preserved salmon eggs served as bait. A 30' x 4' seine with 1/8-inch bar mesh was used to collect stickleback from shoal areas. Fifty stickleback were randomly selected and preserved from each weekly seine sample. Whenever possible, 25 fish were preserved from each minnow trap after the total catch was enumerated.

A 31-gallon aquarium, equipped with an electric air pump and charcoal filter, was used to monitor stickleback spawning activities. The incubation period of stickleback eggs was determined by observing natural and artificial spawn in the aquarium. Eggs stripped from gravid females and fertilized with macerated testes were incubated in perforated plastic containers placed in the aquarium.

Apparatus for the rotenone and squoxin bioassays consisted of covered plastic containers lined with disposable polyethylene bags. Each vessel contained 10 liters of water in which an airstone was suspended. Compressed air was supplied throughout the tests.

Rotenone assays were conducted with an emulsion (trade name Chem-Fish Synergized) containing the following ingredients: 52.5% methylated napthalene; 2.5% rotenone; 5.0% other cube extractives; 2.5% technical piperonyl butoxide; and 37.5% inert ingredients. The toxicant was applied at the desired concentration in each vessel based on a 5% actual rotenone content.

Aliquots of squoxin were dispensed to the containers from a solution containing 100 ml of acetone per gram of compound.

Both powdered (6.85%) and emulsified rotenone (2.5%) were used to treat Cabin Lake. The toxicant was applied at 1.8 ppm based on a 5% rotenone level. Burlap bags, containing powdered rotenone, were pulled behind a boat in the outboard motor's wash and the emulsion was sprayed on the shoreline with a portable fire pump.

Monofilament and multifilament gill nets (125' x 6') having five mesh sizes ranging from 3/4- to 2-inch bar measure were used to collect specimens and measure relative abundance. Nets were set for approximately 24 hours.

When necessary, the age of planted salmonids was determined by examining scales with a microprojector. Fork lengths were recorded to the nearest millimeter and weights to the nearest 0.01 pound.

Lake trout were captured from Skilak Lake by gill nets having mesh sizes ranging from 3/4- to 2-inch bar measure. The fish were held in holding pens prior to being transported to Upper Summit Lake by hatchery tank truck. Oxygen was supplied during the 1 1/4 hours that the fish were in transit.

FINDINGS

Stickleback Studies

The use of rotenone for removing undesirable fish in Southcentral Alaska lakes is a well-accepted and frequently used management practice. Although rotenone has been used extensively, lake rehabilitation has not been consistently successful because of difficulties in eliminating threespine stickleback, *Gasterosteus aculeatus*. Factors causing these inconsistencies must be understood if the recreational potential of many lakes is to be realized.

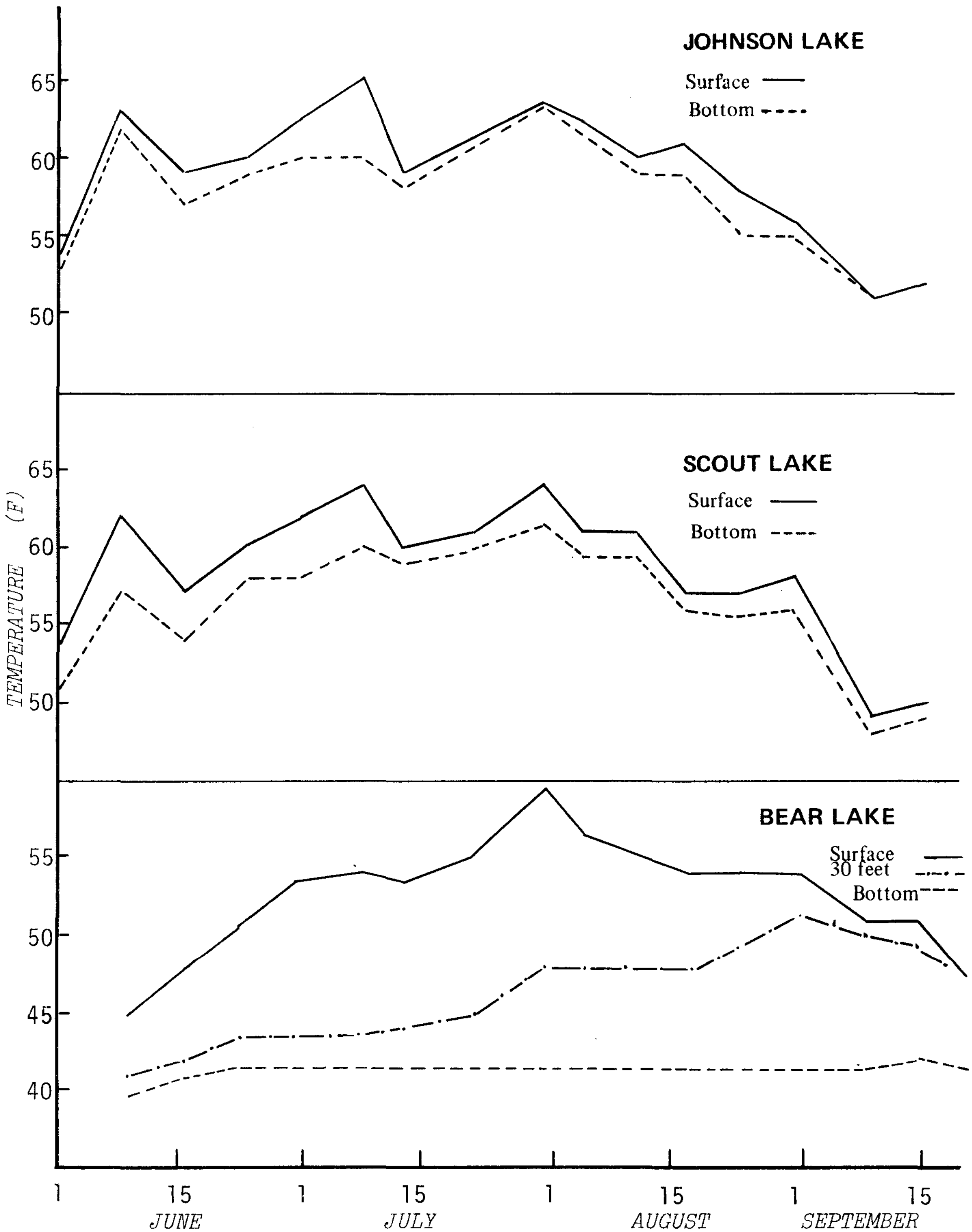

FIGURE 1 TEMPERATURES OF JOHNSON, SCOUT, AND BEAR LAKES DURING THE SUMMER, 1970.

This study was designed to investigate various aspects of the stickleback's life history which may relate to their control with toxicants. Three lakes with varied physical, chemical, and biological characteristics were selected for study. In the past each lake was unsuccessfully treated with rotenone to eliminate threespine stickleback.

Johnson and Scout lakes, located on the western Kenai Peninsula, are representative of the area's land-locked lakes. The water in both lakes has a brownish cast and is low in carbonates (20 - 40 ppm) and total dissolved solids (50 - 80 ppm). The pH ranges from 6.3 - 6.8.

Johnson Lake has a surface area of 85 acres and maximum and mean depths of 16.0 and 10.1 feet, respectively. Floating muskeg comprises much of the shoreline and aquatic vegetation in the form of lilly pads and potamogeton is extensive. Threespine stickleback and silver salmon, *Oncorhynchus kisutch*, inhabit the lake.

Scout Lake has 95 surface acres and maximum and mean depths of 24.0 and 12.7 feet, respectively. With the exception of small beds of lilly pads, aquatic vegetation is sparse. The bottom is composed of gravel and mud along the shore and detritus in the deeper areas. The lake contains threespine stickleback, silver salmon, and rainbow trout, *Salmo gairdneri*.

Bear Lake, located on the eastern Kenai Peninsula, is the site of an anadromous silver salmon enhancement project. The 445-acre lake has three inlets and is drained by Bear Creek. Maximum and mean depths are 65.0 and 34.0 feet, respectively. Aquatic vegetation is sparse. The water is clear, has a pH ranging from 6.8 - 7.0, and is low in carbonates (30 - 50 ppm) and total dissolved solids (60 - 90 ppm). The fishes of Bear Lake include threespine stickleback, Dolly Varden, *Salvelinus malma*, silver salmon, red salmon, *O. nerka*, and rainbow trout.

Johnson and Scout lakes, being relatively small and shallow, have warmer surface and bottom temperatures throughout the summer than Bear Lake. Temperatures recorded during the summer, 1970, are shown in Figure 1.

Population Characteristics:

Stickleback were collected weekly by beach seine and minnow traps to determine seasonal distribution, population characteristics, and period of spawning. Sampling was initiated at Johnson and Scout lakes on May 26 and continued through September 7. Length frequency histograms are presented for both Johnson and Scout lakes in Figures 2 through 7. The length frequency distributions for both populations are comparable to data from Bare and Karluk lakes where Greenbank and Nelson (1959) found most stickleback to have a life span of 2 1/4 years. Greenbank and Nelson also suggested that an occasional fish may survive a third winter.

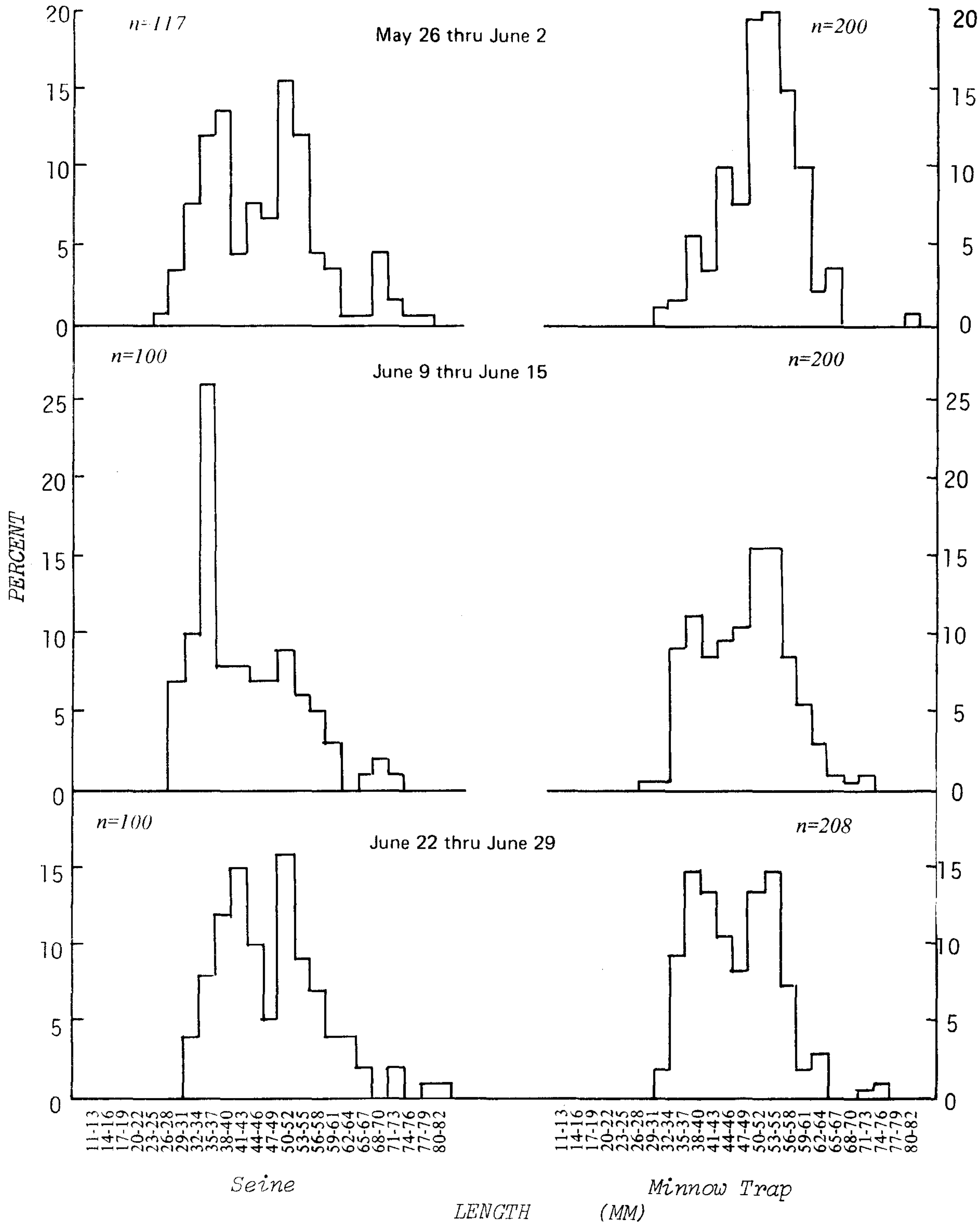

FIGURE 2 LENGTH-FREQUENCY HISTOGRAMS OF STICKLEBACK FROM JOHNSON LAKE, 1970.

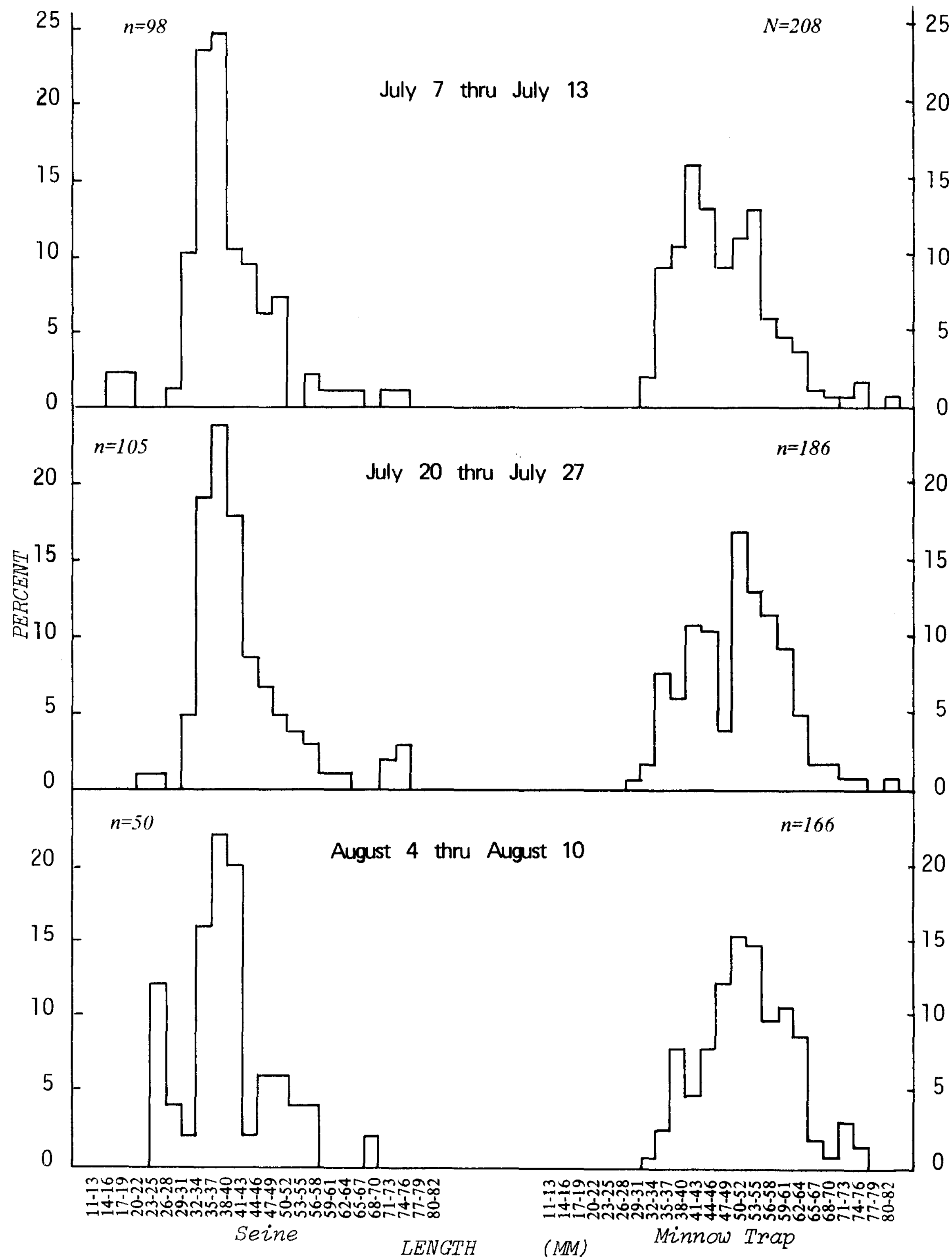

FIGURE 3 LENGTH-FREQUENCY HISTOGRAMS OF STICKLEBACK FROM JOHNSON LAKE, 1970.

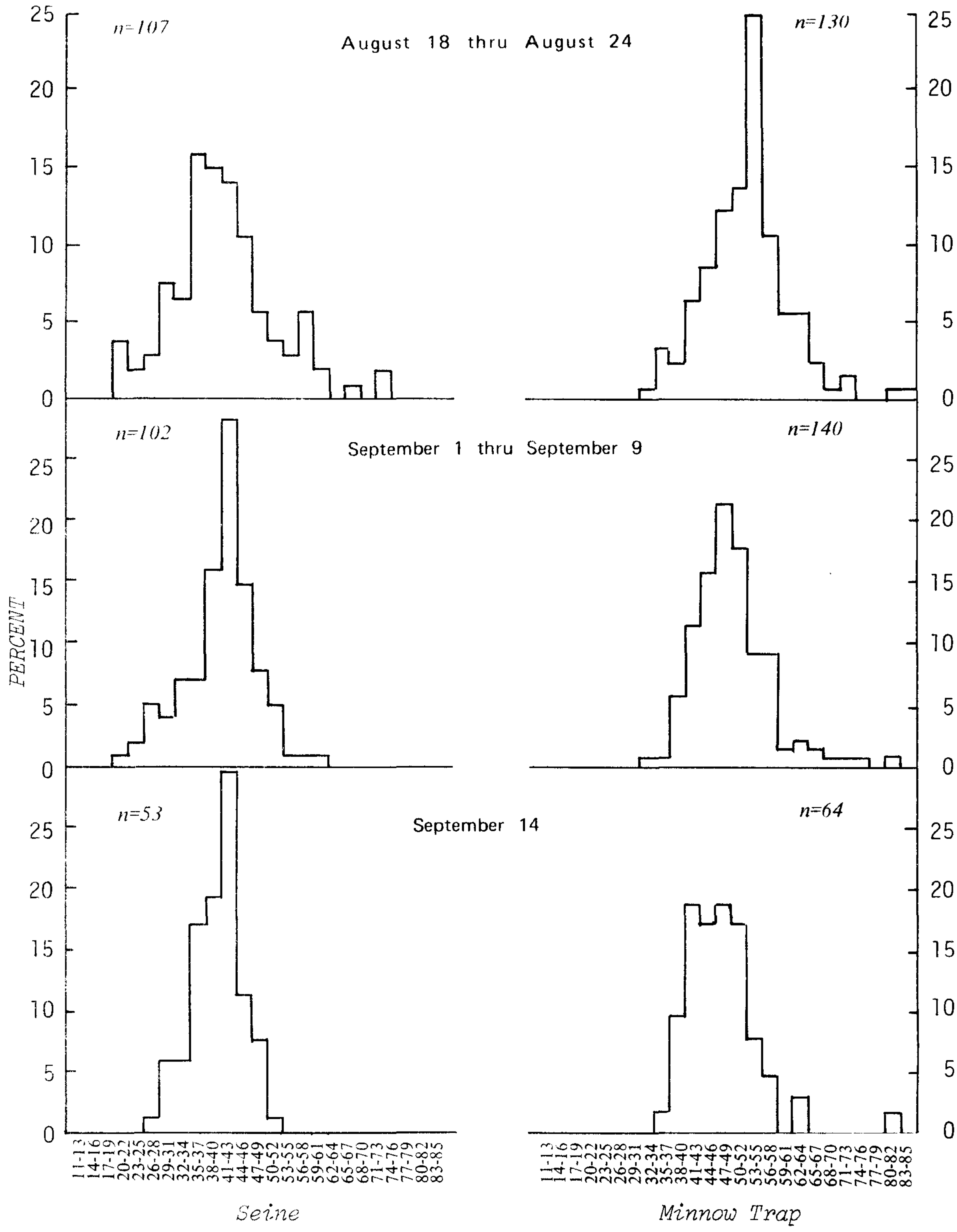

FIGURE 4 LENGTH-FREQUENCY HISTOGRAMS OF STICKLEBACK FROM JOHNSON LAKE, 1970.

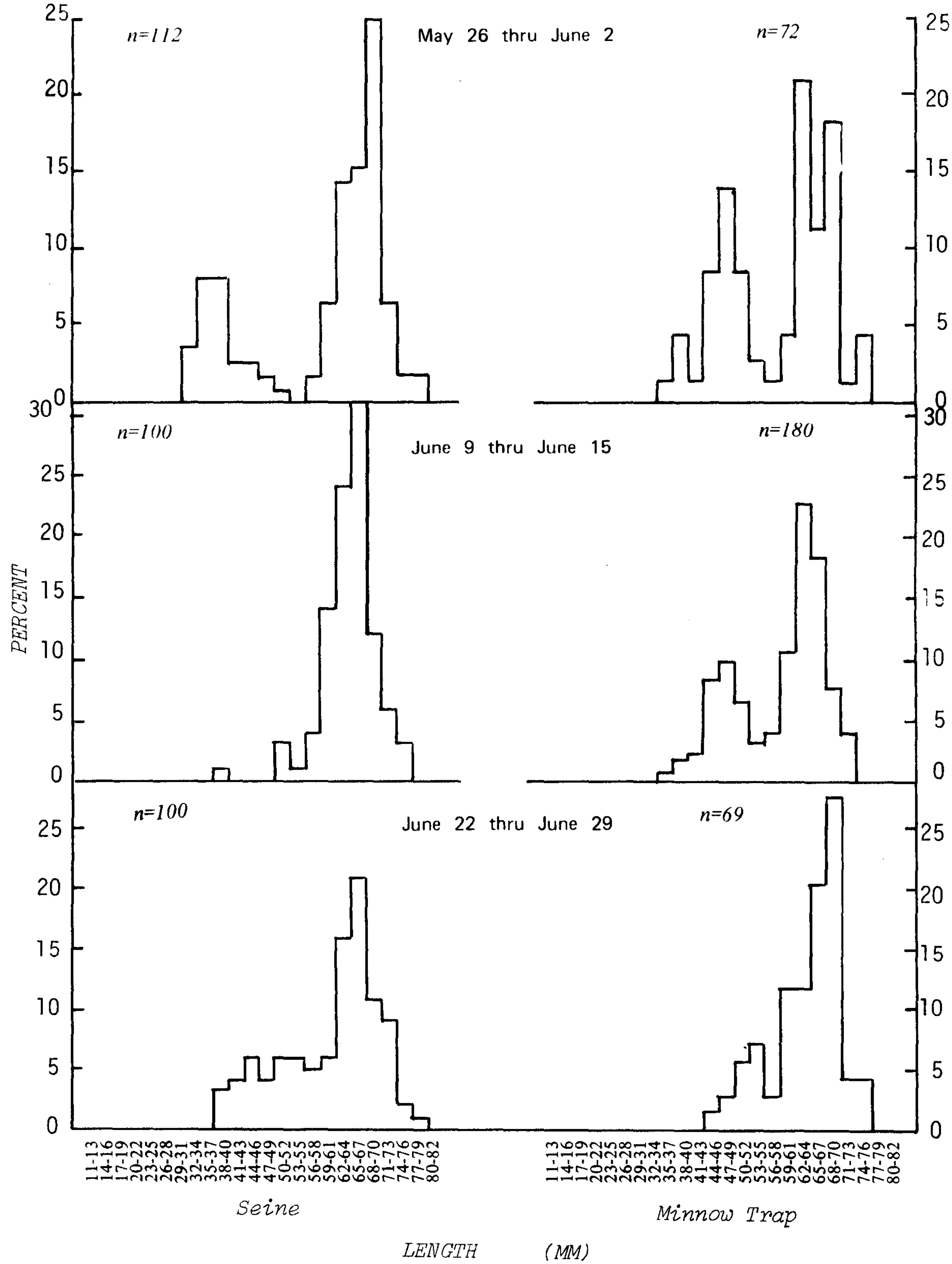

FIGURE 5 LENGTH-FREQUENCY HISTOGRAMS OF STICKLEBACK FROM SCOUT LAKE, 1970.

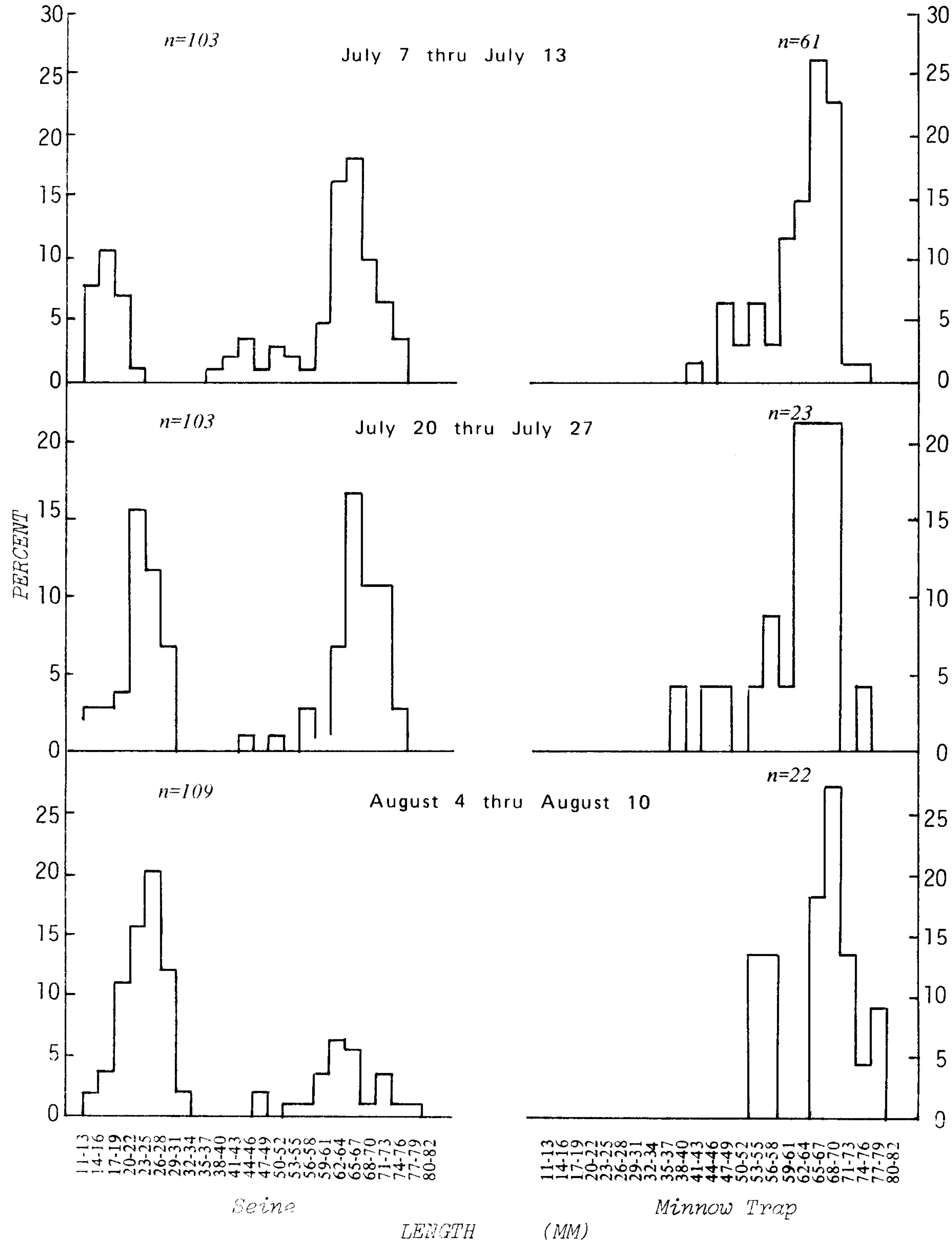

FIGURE 6 LENGTH-FREQUENCY HISTOGRAMS OF STICKLEBACK FROM SCOUT LAKE, 1970.

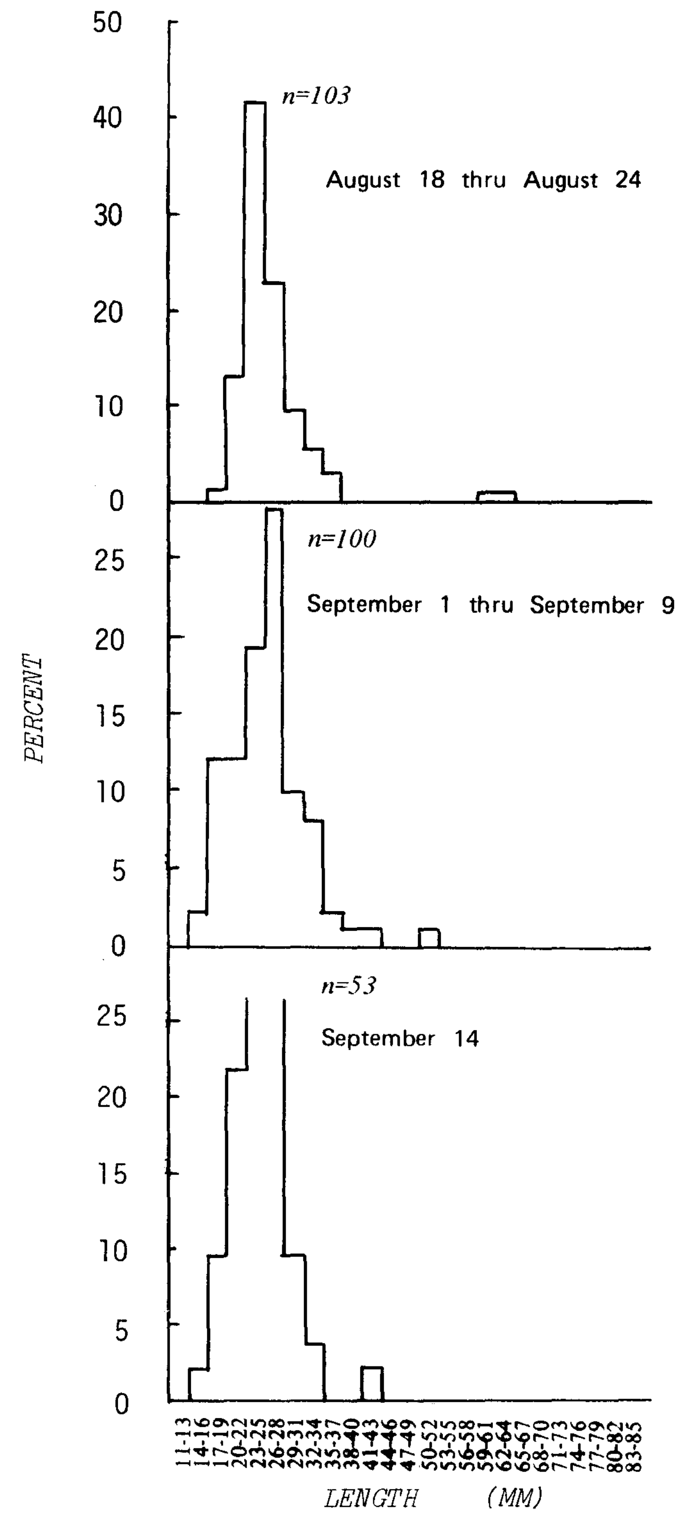

FIGURE 7 LENGTH-FREQUENCY HISTOGRAMS OF SEINE-CAUGHT STICKLEBACK FROM SCOUT LAKE, 1970.

The two major size groups present in the late May samples from Johnson and Scout lakes indicate a life span of 2+ years. The additional size group in Johnson Lake, composed of a few large fish, may represent three-year-old fish. Age analyses were not performed to confirm the age structure of either population. Young-of-the-year entered the samples in both lakes on July 7 and fairly rapid growth occurred during the remainder of the summer. A somewhat slower but steady growth was recorded from stickleback thought to be age I. The successively smaller numbers of large fish as the summer progressed suggest that most stickleback die after spawning. Dead or emaciated fish along the shorelines during late summer tend to substantiate this belief.

The growth of Scout Lake stickleback appeared superior to that of Johnson Lake fish. The frequency mode of Johnson and Scout lakes stickleback, thought to be age II, were about 68 and 51 mm, respectively. Age I stickleback were abundant in Johnson Lake but apparently weak in the Scout Lake population. Young-of-the-year, while occasionally encountered in Johnson Lake, began to dominate the Scout Lake samples in late July.

Bear Lake was sampled similar to Johnson and Scout lakes, except the study began June 9 and terminated September 22. Length frequency histograms of seine- and trap-caught stickleback are shown in Figures 8 through 10. These data differ from Johnson and Scout lakes length distribution patterns. A unimodal distribution with a mode of about 48 mm existed in all June samples. Beginning July 7 and continuing throughout the remainder of the study, smaller fish began to appear in the samples in increasing numbers. The small fish were presumed to be either young-of-the-year or a late-hatched brood from the previous year. If the small fish were young-of-the-year they displayed more rapid growth than Johnson and Scout lakes first-year fish. Prolonged spawning and slow growth may have caused considerable overlap in age groups; hence, a size distribution with a unimodal appearance. Age analysis appears necessary to determine the Bear Lake population's age structure.

Many stickleback were noted to harbor the plerocercoid larvae of the cestode Schistocephalus. A single larvae often filled the entire body cavity and caused considerable distension of the abdomen. Although quantitative measurements were not obtained, at least 25% of the Johnson and Scout lakes adults were infected, whereas fewer than 1% of the Bear Lake stickleback contained the larvae.

Depth Distribution:

The seasonal depth distribution of stickleback was assessed by weekly sampling with baited minnow traps. A permanent station, consisting of a series of traps from the surface to the lake bottom, was established in each lake to measure vertical distribution. The vertical traps in Johnson, Scout, and Bear lakes were positioned in open-water areas at depths of 13, 20, and 60 feet, respectively. Minnow traps were also placed on the bottom of Bear Lake at 10-foot depth intervals to a maximum depth of 60 feet. The traps were specific toward adult fish because of the 3/16-inch mesh size. Results of the vertical sampling are shown in Table I.

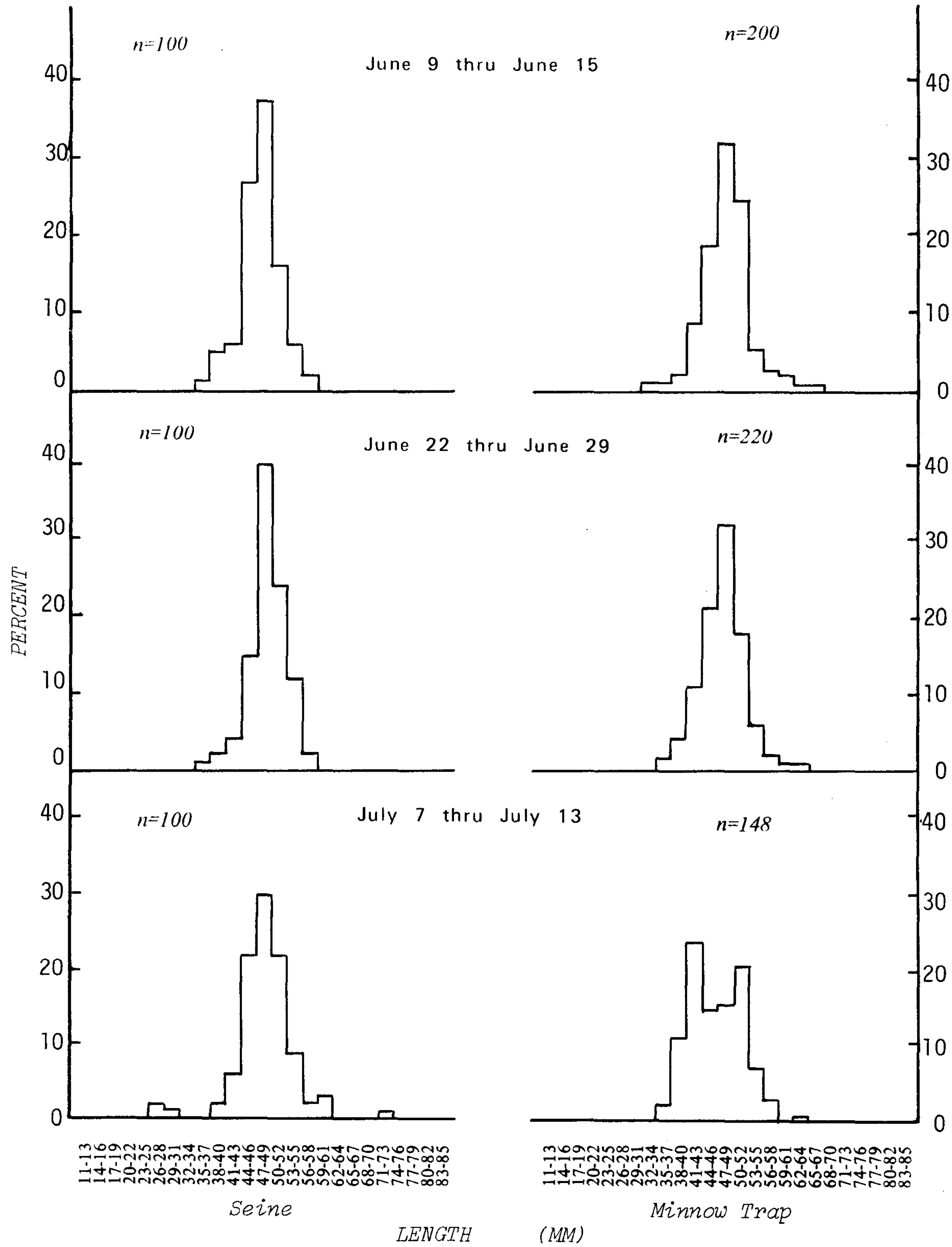

FIGURE 8 LENGTH-FREQUENCY HISTOGRAMS OF STICKLEBACK FROM BEAR LAKE, 1970.

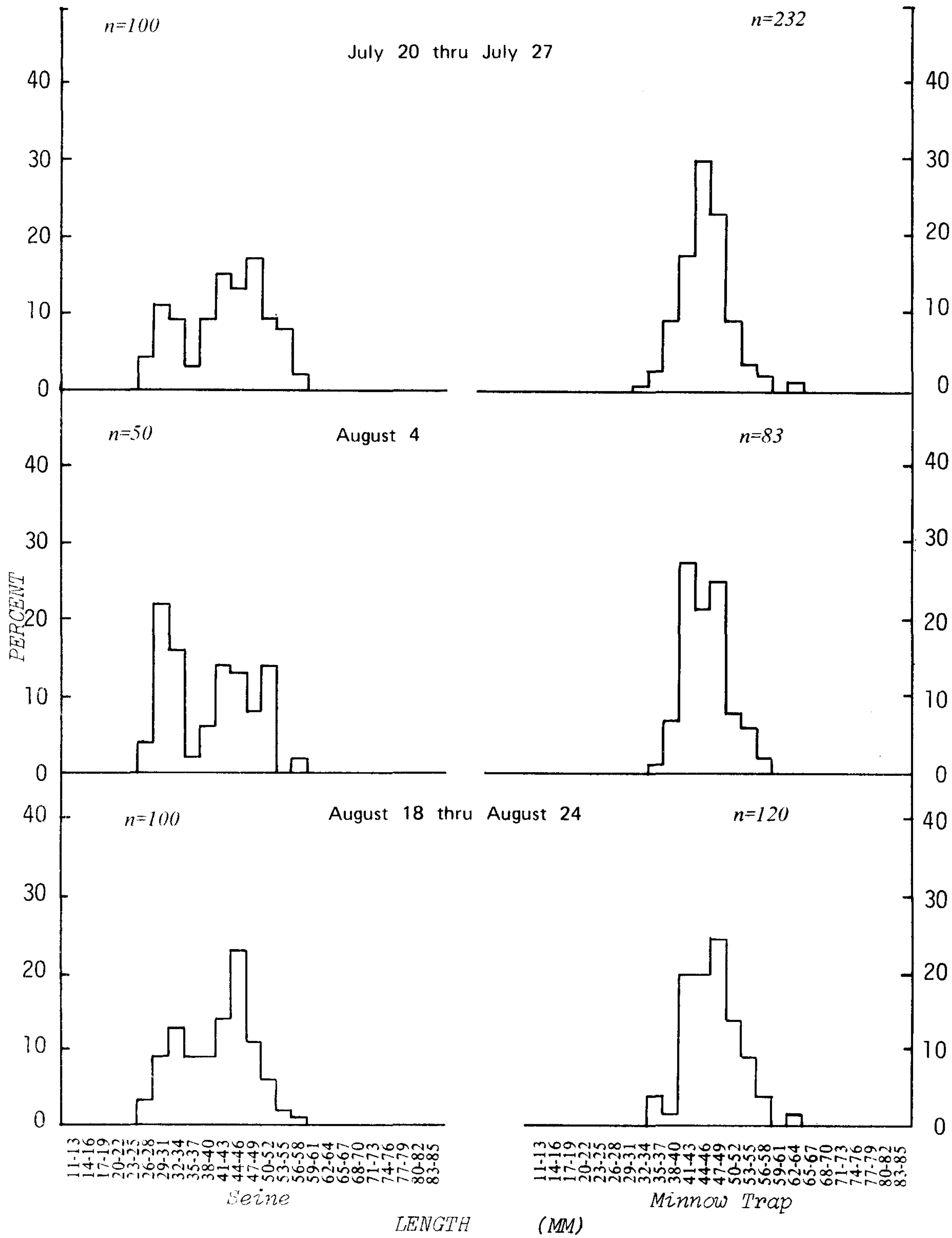

FIGURE 9 LENGTH-FREQUENCY HISTOGRAMS OF STICKLEBACK FROM BEAR LAKE, 1970.

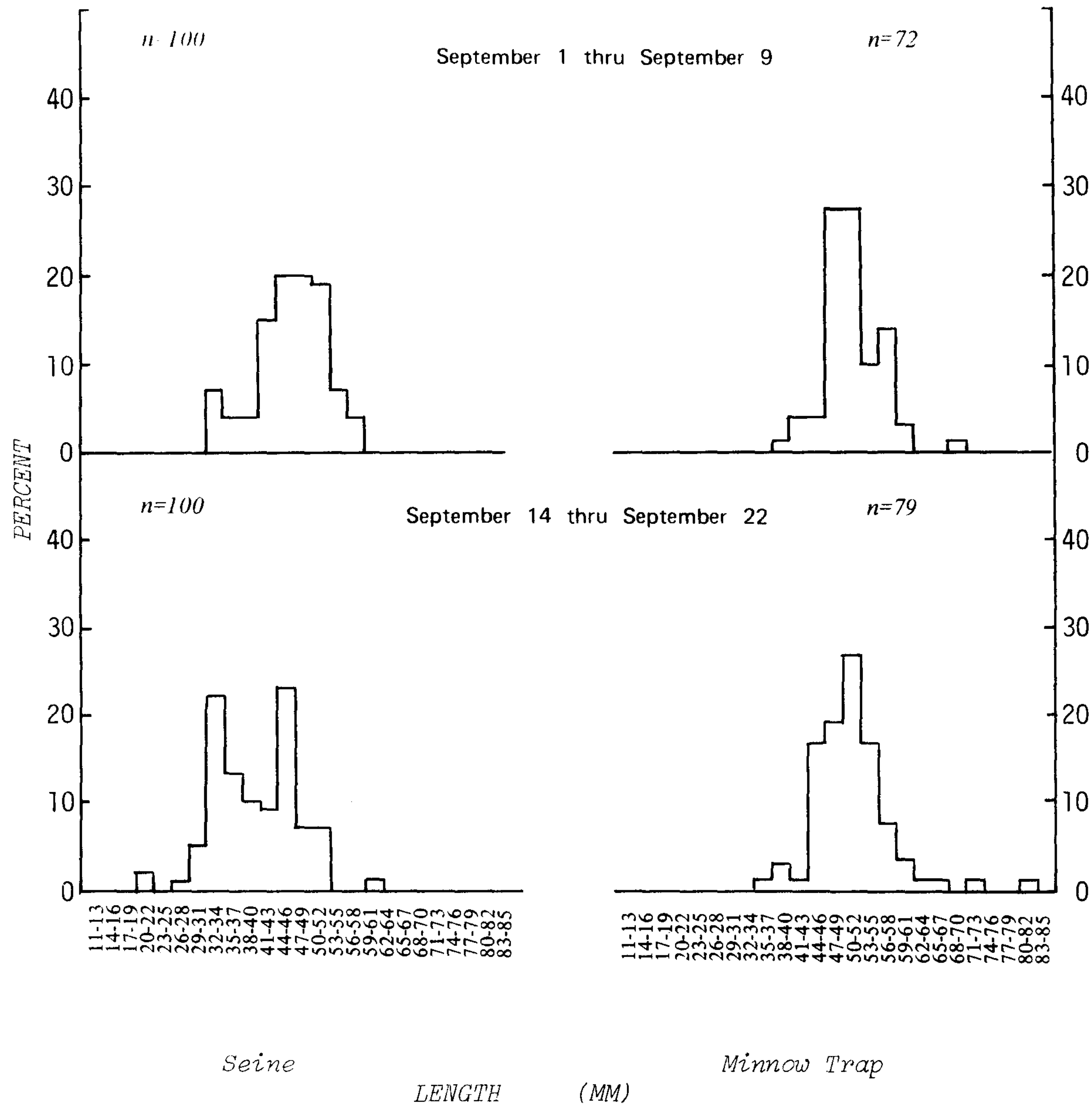

FIGURE 10 LENGTH-FREQUENCY HISTOGRAMS OF STICKLEBACK FROM BEAR LAKE, 1970.

TABLE 1 Depth Distribution of Threespine Stickleback in Johnson, Scout, and Bear Lakes, 1970.

		May		June		July		August		September		Combined	
Lake	Depth (Ft.)	No. Fish	%	No. Fish	%	No. Fish	%	No. Fish	%	No. Fish	%	No. Fish	%
Johnson	0	93	28.7	593	21.5	419	25.8	370	48.6	58	29.1	1,533	27.1
	3	103	31.8	789	28.7	460	28.4	86	11.3	25	12.6	1,463	25.8
	8	35	10.8	719	26.1	334	20.6	65	8.5	17	8.5	1,170	20.7
	13	93	28.7	653	23.7	409	25.2	241	31.6	99	49.8	1,495	26.4
Totals		324	100.0	2,754	100.0	1,622	100.0	762	100.0	199	100.0	5,661	100.0
Scout	0	2	7.4	13	2.3	9	9.0	12	27.9	1	25.0	37	5.0
	5	0	--	54	9.6	3	3.0	6	14.0	0	--	63	8.5
	10	0	--	59	10.5	1	1.0	2	4.6	0	--	62	8.4
	15	0	--	88	15.6	6	6.0	3	7.0	0	--	97	13.2
	20	25	92.6	350	62.0	81	81.0	20	46.5	3	75.0	479	64.9
Totals		27	100.0	564	100.0	100	100.0	43	100.0	4	100.0	738	100.0
Bear	0	-	--	116	16.5	292	32.0	37	7.1	22	6.7	467	18.9
	10	-	--	96	13.7	215	23.5	12	2.3	6	1.8	329	13.3
	20	-	--	256	36.5	197	21.6	13	2.5	4	1.2	470	19.1
	30	-	--	75	10.7	152	16.6	269	51.5	2	0.6	498	20.2
	40	-	--	14	2.0	29	3.2	112	21.5	13	3.9	168	6.8
	50	-	--	13	1.9	8	0.9	8	1.5	92	27.8	121	4.9
	60	-	--	131	18.7	20	2.2	71	13.6	192	58.0	414	16.8
Totals				701	100.0	913	100.0	522	100.0	331	100.0	2,467	100.0

Johnson Lake stickleback appeared randomly distributed at all depths in late May, June, and July, however, during August and September the fish displayed a preference for either the surface or bottom.

Scout Lake stickleback showed a preference for the bottom throughout the investigation. The reduction in catches as the summer progressed presumably occurred because adults die after spawning.

The vertical trap series in Bear Lake revealed stickleback at all depths throughout the summer and fall. Sixty-seven and 77% of the stickleback were captured above the 30-foot level during June and July, respectively. In August, 73% of the stickleback were captured at depths of 30 and 40 feet, whereas in September, 86% of the fish were taken within 10 feet of the bottom.

A possible explanation for the increased depth of capture as the summer progressed lies in the stickleback's high utilization of plankton. It is hypothesized that summer depth distribution is strongly influenced by the area of maximum plankton production. Cursory observation of the food habits of Bear Lake stickleback indicates that zooplankton is a major summer food. The stickleback's association with the bottom during September may reflect a seasonal change in diet, however, detailed food studies were not conducted in Bear Lake to confirm this possibility.

Stickleback were abundant along the shore of Bear Lake throughout the study. Weekly seine catches averaged 54.1 stickleback per round haul. Trap catches from the lake bottom near shore to a 60-foot depth indicated that Bear Lake stickleback are primarily shallow-water inhabitants. Table 2 shows that bottom catches decreased with increased depth. The seasonal catch from six bottom traps was five times that of six traps suspended at various depths in open water.

Spawning:

There is little agreement in the literature regarding the spawning time of threespine stickleback. Carl (1953) found that spawning occurs from about the first week in April to the first week in September in Cowichan Lake, British Columbia. Greenbank and Nelson (1959) reported ripe Karluk Lake females as late as August 3. They also observed ripe females in Bare Lake as early as May 23 and as late as July 29. Vrat (1949) found that central California stickleback spawn from February or March to mid-August. Undoubtedly, spawning time varies due to differences in races or environmental conditions.

Gravid females were abundant in the May 29 Johnson Lake samples. The exact date spawning began was not determined; however, a few spawned-out females were observed on June 2. The frequency of occurrence of gravid females in the seine samples suggest that spawning peaked between June 2 and June 15. No gravid females were collected after June 29.

TABLE 2 Catches of Threespine Stickleback from the Bottom of Bear Lake, 1970.

Bottom Depth (Ft.)	June No. Fish	June %	July No. Fish	July %	August No. Fish	August %	September No. Fish	September %	Combined No. Fish	Combined %
10	608	25.4	1,111	41.9	563	23.7	584	19.9	2,866	27.7
20	527	22.0	1,017	38.3	741	31.2	548	18.7	2,833	27.4
30	419	17.5	295	11.1	776	32.6	881	30.1	2,371	22.9
40	420	17.6	190	7.2	201	8.5	505	17.3	1,316	12.7
50	286	12.0	21	0.8	26	1.0	216	7.4	549	5.3
60	131	5.5	20	0.7	71	3.0	192	6.6	414	4.0
Totals	2,391	100.0	2,654	100.0	2,378	100.0	2,926	100.0	10,349	100.0

Samples from Scout Lake on May 29 contained many ripe females. Spawned-out females were first observed on June 9 and the peak of spawning probably occurred between June 15 and July 6. No females containing ripe eggs were collected after July 20; however, spawned-out females were present until August 4.

The spawning period for Bear Lake stickleback occurred over a prolonged period. Gravid females were present when sampling began on June 9 and the numbers of ripe fish remained high until July 14, although a few ripe fish were collected weekly until August 18. With the exception of two gravid females on September 15, no ripe fish were collected during the remainder of the study.

Of the 1,074 Bear Lake stickleback examined during June, 47.6% were spawners. Sexually mature fish were collected from all depths. Mean lengths for ripe males and females were 50.5 and 49.5 mm, respectively. Mature males ranged from 39 - 64 mm in length, whereas females ranged from 41 - 82 mm. Males judged to be immature averaged 46.8 mm and ranged from 34 - 60 mm in length. Immature females ranged from 32 - 66 mm and had a mean of 47.4 mm.

Spawning habits and incubation periods were studied in an aquarium containing stickleback, water, sand, and vegetation from Scout Lake. Spawning activities were similar to those described by Vrat (1949) except that leaves and twigs were commonly used to cover or line a nest composed of sand. After completion of the nest, the male induced one or more females into it where the eggs were laid and immediately fertilized. In addition to vigorously defending the nest, the male frequently fanned the entrance (eggs) with his pectoral fins.

The incubation period for stickleback eggs appears correlated with water temperatures. Greenbank and Nelson (1959) report that eggs from Bare Lake stickleback hatch in 14 days at water temperatures varying from 48.2° - 60.8°F (09.0° - 16.0°C). Vrat (1949) states that California stickleback eggs hatch in 140 hours (5.8 days) at a water temperature of 63°F (17.2°C). Spawn from Scout Lake stickleback, incubated in the aquarium at temperatures varying from 70° - 73°F (21.1° - 22.8°C) hatched in five days. Eggs stripped from ripe females and fertilized with macerated testes hatched in 5 1/2 days at temperatures ranging from 68° - 71°F (20.0° - 21.7°C).

Rotenone Assays:

Information concerning the susceptibility of Alaska stickleback to rotenone is scanty. Redick[1] stated that stickleback reappeared in seven lakes shortly after treatment with 0.5 ppm rotenone. He also noted

[1]Summary of Past Chemical Treatments in Alaska by Sport Fish Personnel. By R. Russell Redick. Alaska Department of Fish and Game Staff Report. Typewritten, 12 pp., 1970.

complete and incomplete eradication in landlocked lakes treated at concentrations of 0.75 and 1.5 ppm, respectively.

To assess the toxicity of rotenone to stickleback, bioassays were conducted with Johnson Lake water and fish. Assay fish ranged from 34 - 55 mm and had a mean length of 40.3 mm. Ten stickleback were placed in each vessel prior to application of emulsified rotenone at concentrations varying from 0.25 - 1.25 ppm of 5% rotenone. Assays were conducted for 48 hours at temperatures ranging from 54° - 58°F (12.2° - 14.4°C), and from 65° - 68°F (18.3° - 20.0°C). Mortality due to incidental injury was believed low because no control fish died during the tests.

Assay results show that the stickleback survival period is appreciably shortened both by higher temperatures and greater concentrations (Tables 3 and 4). The minimum LC_{100} was 0.5 ppm at each temperature range tested; however, substantial mortality also occurred in fish exposed to 0.25 ppm. The data suggest that prolonged exposure to 0.25 ppm rotenone may result in 100% mortality.

TABLE 3 Mortality of Threespine Stickleback Exposed to Several Concentrations of Rotenone at Water Temperatures Ranging from 54° - 58°F (12.2° - 14.4°C).

Concentration of 5.0% Rotenone (ppm)		Exposure (Hrs.) 12	24	36	48
Control:	Live	10	10	10	10
	Dead	0	0	0	0
0.25:	Live	10	9	9	6
	Dead	0	1	1	4
0.50:	Live	3	1	0	-
	Dead	7	9	10	-
0.75:	Live	1	0	-	-
	Dead	9	10	-	-
1.00:	Live	0	-	-	-
	Dead	10	-	-	-
1.25:	Live	0	-	-	-
	Dead	10	-	-	-

TABLE 4 Mortality of Threespine Stickleback Exposed to Several Concentrations of Rotenone at Water Temperatures Ranging from 65° - 68°F (18.3° - 20.0°C).

Concentration of 5.0% Rotenone (ppm)		Exposure (Hrs.) 12	24	36	48
Control:	Live	10	10	10	10
	Dead	0	0	0	0
0.25:	Live	6	3	2	2
	Dead	4	7	8	8
0.50:	Live	0	-	-	-
	Dead	10	-	-	-
0.75:	Live	0	-	-	-
	Dead	10	-	-	-
1.00:	Live	0	-	-	-
	Dead	10	-	-	-
1.25:	Live	0	-	-	-
	Dead	10	-	-	-

Squoxin Assay:

An experiment to measure toxicity of squoxin (1,1'-methylenedi-2-naphthol monosodium salt) to stickleback was performed using the same techniques and apparatus as described in the rotenone assays. MacPhee and Ruelle (1969) found squoxin kills northern squawfish, Ptychocheilus oregonensis, at concentrations not lethal to certain salmonoids but made no mention of the piscicide's effect on threespine stickleback.

Assays were made with Johnson Lake water and fish. Test fish had a mean length of 39.8 mm and ranged from 32 - 51 mm. Temperatures varied from 57° - 61°F (13.9° - 16.1°C) during the 48-hour test.

Test results revealed that the LC_{100} was 0.5 ppm (Table 5). Considerable mortality also occurred when stickleback were exposed to 0.3 ppm but few fish died at a concentration of 0.1 ppm. Survival time decreased with increased concentrations.

Although conclusions based on one laboratory experiment may be tenuous, the data indicate that squoxin has little value as a selective stickleback piscicide. Concentrations lethal to stickleback were similar to concentrations toxic to many salmonids. MacPhee and Ruelle (1969) found the maximum LC_0 to be about 0.3 ppm for brook trout, S. fontinalis, 0.1 ppm for king salmon, O. tshawytscha, and from 0.6 - 1.3 ppm for silver salmon and rainbow trout depending on water temperatures.

TABLE 5 Mortality of Threespine Stickleback Exposed to Several Concentrations of Squoxin at Water Temperatures Ranging from 57° - 61°F (13.9° - 16.1°C).

Squoxin Concentration (ppm)		Exposure (Hrs.) 12	24	36	48
Control A:	Live	9	9	9	9
	Dead	1	1	1	1
Control B:	Live	10	10	10	10
	Dead	0	0	0	0
0.1:	Live	9	8	8	8
	Dead	1	2	2	2
0.3:	Live	4	1	1	1
	Dead	6	9	9	9
0.5:	Live	3	1	0	-
	Dead	7	9	10	-
0.7:	Live	1	0	-	-
	Dead	9	10	-	-
0.9:	Live	3	0	-	-
	Dead	7	10	-	-
1.0:	Live	1	0	-	-
	Dead	9	10	-	-
1.5:	Live	0	-	-	-
	Dead	10	-	-	-
2.0:	Live	0	-	-	-
	Dead	10	-	-	-

Bioassay results indicate that rotenone is the least expensive of the two toxicants for use in Alaska. The cost of lake treatment with squoxin at 0.5 ppm would be four-to-five times greater than treatment with 0.5 ppm of 5% emulsified rotenone. Application of powdered rotenone would reduce cost even further.

Cabin Lake Studies:

This study was designed to observe the effect of rotenone on stickleback in a shallow landlocked lake and to determine the period necessary for detoxification. Cabin Lake, with a surface area of 53 acres and a maximum depth of 20 feet, was selected for study. Methyl orange alkalinity and pH values immediately after rehabilitation were 17.0 ppm and 6.5, respectively. Temperature profiles during the period of toxicity are presented in Table 6.

TABLE 6 Cabin Lake Temperature Profiles, °F and (°C), during the Period of Toxicity, 1970.

Date	Sample Depth 0'	3'	6'	9'	12'	15'
6/19	58 (14.4)	57 (13.9)	57 (13.9)	57 (13.9)	57 (13.9)	57 (13.9)
6/30	62 (16.7)	62 (16.7)	62 (16.7)	61 (16.1)	61 (16.1)	61 (16.1)
7/ 7	66 (18.9)	65 (18.3)	63 (17.2)	63 (17.2)	63 (17.2)	62 (16.7)
7/14	61 (16.1)	61 (16.1)	61 (16.1)	61 (16.1)	61 (16.1)	61 (16.1)
7/21	61 (16.1)	61 (16.1)	61 (16.1)	61 (16.1)	61 (16.1)	61 (16.1)
8/ 4	61 (16.1)	61 (16.1)	61 (16.1)	61 (16.1)	61 (16.1)	61 (16.1)
8/11	63 (17.2)	63 (17.2)	63 (17.2)	62 (16.7)	62 (16.7)	62 (16.7)
8/18	58 (14.4)	58 (14.4)	58 (14.4)	58 (14.4)	58 (14.4)	58 (14.4)

The lake was treated on June 18 with 1.8 ppm of 5% rotenone. Thousands of dead or dying stickleback were noted less than two hours after treatment. Caged stickleback, suspended from the surface to the lake bottom, were dead less than 20 hours after rotenone application. Scuba and above-surface reconnaissance suggested a complete stickleback kill.

Juvenile silver salmon were placed in the lake on a weekly basis to measure the rate of rotenone breakdown. These tests indicated the lake was toxic to fish at all depths for approximately 40 days. Thereafter the rate of rotenone breakdown apparently decreased with increased depth. Fish exposed on August 4 and 11 (47 and 54 days after treatment) experienced substantial mortality in the deeper water and little mortality near the surface (Table 7). Cabin Lake remained toxic to silver salmon for 57 - 60 days.

TABLE 7 Survival of Silver Salmon in Cabin Lake after Treatment with Rotenone on June 18, 1970.

		Survival after Various Exposures					
		24 Hrs.		48 Hrs.		72 Hrs.	
Date*	Depth (Ft.)	Live	Dead	Live	Dead	Live	Dead
8/ 4	0	8	0	7	1	-	-
	5	2	3	2	3	-	-
	10	1	4	0	5	-	-
	15	0	6	0	6	-	-
8/11	0	5	0	4	1	-	-
	5	5	0	3	2	-	-
	10	5	0	3	2	-	-
	15	5	0	1	4	-	-
8/18	0	5	0	5	0	5	0
	5	5	0	5	0	5	0
	10	5	0	5	0	5	0
	15	5	0	5	0	5	0

*Prior to 8/4/70, silver salmon died at all depths within 24 hours.

Discussion:

Several facts concerning the proper use of rotenone are apparent from these data. Salient life history features which may relate to stickleback control are as follows: (1) stickleback are abundant throughout the ice-free period of the year; (2) the species is primarily a shallow-water inhabitant but substantial numbers of fish occupy all depths; (3) the normal life span is probably 2+ years and most fish die shortly after spawning; (4) at least two age groups are present throughout the year; (5) spawning begins in late spring and may continue until August; (6) stickleback eggs hatch in five or six days at 70°F (21.1°C).

Laboratory assays show that 0.5 ppm of 5% rotenone is lethal to stickleback; however, concentrations of 0.5 ppm frequently fail to eliminate all stickleback from the natural environment. These observations strongly suggest that detoxification influences of the biotope increase the possibility of stickleback survival. Stickleback abound in the floating muskeg and weedy areas that characterize the margin of many lakes. Uniform application of rotenone in these areas is difficult, and the absorption and breakdown of rotenone in dense organic matter is rapid.

Summer treatment has been a common practice in Alaska because the waters are ice-free during a relatively short time. High water temperatures, extensive daylight, and maximum vegetative growth during the summer undoubtedly increases detoxification in shoal areas where stickleback are abundant. Thermal stratification also enhances the chance of improper dispersion of the toxicant in deep water.

These observations suggest that Alaskan lakes can be treated more effectively during the fall prior to ice formation. At this time, the fall overturn will thoroughly mix the rotenone, vegetation will be minimal, and stickleback will have completed spawning. Detoxification will be slow under an ice and snow cover because of low temperatures and light intensity. Muskeg and marshy areas, which provide avenues of escape during the summer, will be frozen.

In addition to enhancing the chance of a complete kill, fall treatment would allow zooplankton populations to recover before introducing game fish the following summer. Studies show that zooplankton populations may remain at low levels several months after a lake has become nontoxic to fish (Kiser, et. al., 1963). Stocking after zooplankton populations have returned to pretreatment levels would increase survival and growth of planted fish.

The more rapid detoxification of the surface and shoal waters of Cabin Lake exemplifies the importance of testing the toxicity of all depths prior to planting fish. These data also indicate that test fish should be exposed at least 48 hours to insure that treated waters are no longer toxic to fish.

Lake Stocking Evaluations

Hatchery-reared salmonids are being used in increasing numbers to supplement Kenai Peninsula native game fish populations. In past years, most managed lakes have been sampled in the fall to determine proper initial and supplementary stocking rates, including sizes and fish species.

Silver Salmon:

Growth and relative survival rates were evaluated by gill net sampling four lakes stocked with silver salmon. Centennial, Upper Jean, and Scout lakes were planted in the fall, 1969, with fish from the same hatchery lot. Johnson Lake received an initial plant in 1967 and a supplemented plant in the fall, 1968. Threespine stickleback were present in each lake. In addition, Scout Lake contains a few rainbow trout and Upper Jean Lake a small red salmon population.

A comparison of the various plants after one year of lake residency reveals a correlation between growth and stocking density (Table 8). Silver salmon planted at 450, 306, 300, 253, and 219 fish per surface acre averaged 153.6, 171.3, 167.5, 179.3, and 230.4 mm in length, respectively.

TABLE 8 Comparative Lengths, Weights, and Catch Per Gill-Net Hour for Silver Salmon after One Year of Lake Residence.

Lake	Date Planted	Fish/ Lb.	Fish/ Sur. Acre	Length (mm) Range	Length (mm) Mean	Weight (Lbs.)	Catch/ Hr.
Centennial	9/ 9/69	144	219	143 - 294	230.4	0.39	1.27
Upper Jean	9/ 9/69	144	253	150 - 262	179.3	0.17	0.56
Scout	9/ 9/69	144	300	142 - 234	167.5	0.12	1.78
Johnson	10/ 3/67	105	450	138 - 168	153.6	0.08	0.36
	8/28/68	93	306	116 - 185	171.3	0.14	1.10

Relative abundance, as measured by gill net catches, has no apparent relationship with stocking density. Gill nets, however, are a questionable tool for measuring relative abundance because of mesh size selectivity. Because of their small size the Johnson Lake fish would be less vulnerable to capture than the larger Centennial Lake fish. Positioning of the net, light intensity, and weather are but a few of the factors that are known to influence gill-net catch rates.

Scout Lake permits an opportunity to compare silver salmon and rainbow trout growth and survival potentials in a common environment. Rainbow trout, averaging 325 per pound, were planted in the fall, 1966, at a density of 285 fish per surface acre. After one year, the trout ranged from 260 - 331 mm and averaged 300.9 mm. The catch rate was 0.15 fish per gill net hour.

Scout Lake was treated with rotenone in June, 1966; however a complete kill was not obtained. The reduction in stickleback numbers immediately following rehabilitation probably had a beneficial influence on trout growth and survival.

Silver salmon, averaging 144 per pound, were stocked in 1969 at 300 fish per surface acre. These fish averaged 167.5 mm in length during the fall, 1970, and ranged from 142 - 234 mm. The catch rate was 1.78 fish per gill net hour.

Although salmon growth was inferior to that of the trout, they survived in much greater numbers. These observations are similar to those of Redick (1970) who found rainbow trout survival to be much lower than that of silver salmon in many Matanuska Valley lakes. The sparse Scout Lake trout population was seldom fished by sport fishermen, whereas the abundant silver salmon population received considerable fishing effort during the winter of 1970-71.

Rainbow Trout:

Rainbow trout growth and relative survival rates were evaluated by examining gill-net caught fish from three rehabilitated lakes. Threespine stickleback were successfully eliminated from Sport and Arc lakes in 1965. Dolly Varden reappeared after Jerome Lake was treated in 1968 because of an introduction by a local resident. Gill net sampling in Jerome Lake during 1969 (51 hours) and 1970 (46 hours) produced catches of 1 and 12 Dolly Varden, respectively.

TABLE 9 Physical Characteristics of Kenai Peninsula Lakes Stocked with Rainbow Trout.

Lake	Surface Acres	Depth (Ft.) Maximum	Depth (Ft.) Mean	Acre Ft.	Aquatic Vegetation
Sport	72.0	20	10.9	788	Extensive
Arc	16.0	16	8.6	138	Limited
Jerome	16.0	15	8.5	138	Limited

The physical characteristics and stocking rates for each lake are presented in Tables 9 and 10. The 1966 plants of 400 trout per surface acre in Sport and Arc lakes displayed remarkably similar growth rates during succeeding years. Growth was most rapid during the two years following introduction. Supplementary plants in 1968 experienced poorer growth than initial plants but relative survival was similar after one year. Growth of a 1969 Arc Lake plant was less than the two previous plants despite a substantial reduction in stocking density.

TABLE 10 Rainbow Trout Stocking Rates in Three Kenai Peninsula Lakes.

Lake	Date Stocked	Fish/ (Lb.)	Fish/ Surface Acre	Fish/ Acre-Ft.	Tot. Planted
Sport	7/ 7/66	1,160	400	37	29,000
	8/27/68	210	400	37	29,000
Arc	7/ 7/66	1,160	400	46	6,380
	8/27/68	210	310	36	5,000
	9/ 5/69	132	200	23	3,200
Jerome	8/27/68	210	525	62	8,550
	9/ 5/69	132	220	26	3,600

Jerome Lake was initially stocked during the fall, 1968, with 525 trout per surface acre. After one year, these fish were considerably smaller (185 mm), than the initial plants in Sport and Arc lakes (287 mm) but relative survival was greater.

Stocking densities and/or environmental differences presumably are responsible for growth and survival variations. A supplemental plant of 220 trout per acre was made in Jerome Lake in 1969. Gill-net catches during the fall, 1970, revealed that these trout had a growth rate similar to the initial plant but that relative survival was appreciably lower. A summary of gill-net catch data for each of the rehabilitated lakes is presented in Table II.

TABLE II Lengths, Weights, and Catch Per Gill-Net Hour of Rainbow Trout in Three Rehabilitated Lakes.

Lake	Year Stocked	Year Sampled	Age	Length (mm) Range	Length (mm) Mean	Weight (Lbs.)	Catch/ Hr.
Sport	1966	1967	I+	240 - 318	286.4	0.64	0.40
		1968	II+	340 - 397	373.2	1.55	0.47
		1969	III+	388 - 469	419.3	1.86	0.24
		1970	IV+	399 - 448	422.5	2.10	0.07
	1968	1969	I+	215 - 283	246.8	0.64	0.50
		1970	II+	322 - 370	339.4	1.07	0.23
Arc	1966	1967	I+	269 - 312	288.6	0.67	0.27
		1968	II+	335 - 387	373.7	1.61	0.17
		1969	III+	420 - 427	432.0	2.08	0.05
	1968	1969	I+	225 - 264	248.6	0.45	0.29
	1969	1970	I+	192 - 352	230.5	0.32	0.55
Jerome	1968	1969	I+	150 - 253	185.5	0.18	2.43
		1970	II+	260 - 360	301.5	0.80	0.57
	1969	1970	I+	115 - 230	180.3	0.18	0.39

Island Lake, with a surface area of about 270 acres and a maximum depth of 31 feet, was sampled by gill net to evaluate past red salmon and rainbow trout plants. Threespine stickleback are indigenous to the lake. Red salmon smolts were stocked at 64 per surface acre during June, 1968. The fish averaged 70 per pound and were primarily age II. Rainbow trout, averaging 132 per pound, were stocked at a rate of 390 per surface acre in September, 1969.

Eighty-eight hours of gill-net sampling in October, 1970, produced a catch of 5 rainbow trout and 57 red salmon. The trout averaged 258.6 mm in length and ranged from 194 - 311 mm. Red salmon ranged from 124 - 337 mm and had a mean length of 231.5 mm. These observations support prior observations that domestic rainbow trout have satisfactory growth but low survival in lakes containing stickleback.

Johnson Lake, located near the community of Moose Pass at an elevation of 1,350 feet, was stocked in 1963 with 1,640 rainbow trout fingerling in an attempt to establish a self-sustaining fishery. The lake has 43 surface acres, a maximum depth of 35 feet, and is drained by Johnson Creek. No native fish are known to reside in the lake.

Twenty-seven rainbow trout were captured by 46.5 hours of gill-net sampling during June, 1970. The trout had a mean length of 263.1 mm and ranged from 155 - 475 mm. Establishing a self-sustaining population appears likely.

Red Salmon:

Experimental red salmon transplants were evaluated by gill-net sampling six lakes to determine relative survival and growth rates. Smolts captured at the Bear Creek weir near Seward were used for all introductions. The 1965 and 1966 transplants were predominantly age I, whereas the 1967 plant was primarily age II smolts. Table 12 illustrates the lakes and numbers of fish introductions made.

TABLE 12 Numbers of Red Salmon Smolts Stocked in Six Kenai Peninsula Lakes, 1965 - 1968.

Lake	Date Stocked*	Fish/ Surface Acre	Tot. Fish Planted
Upper Jean	1965	25	1,150
	1966	745	34,670
	1967	196	9,020
Portage	1966	644	18,670
	1967	378	10,950
Sunken Island	1966	224	31,350
	1967	94	13,140
Bernice	1966	127	18,500
	1967	152	22,160
Bottinentin	1967	137	38,220
Island	1968	64	17,390

*All lakes were stocked in June of the year indicated.

The physical and chemical features of the recipient waters have been described by Engel (1968; 1969; 1970). Upper Jean, Portage, Island, and Sunken Island lakes have similar characteristics: each exceeds 30 feet in depth and is thermally stratified during the summer. Bottinentin and Bernice lakes, both less than 12 feet deep, exhibit homiothermous summer conditions.

A summary of the 1969 and 1970 gill net catches is shown in Table 13. These data reveal a drastic reduction in the Upper Jean Lake red salmon population. Although the reason for the poor survival is not fully understood, it may be associated with the introduction of 11,500 silver salmon fingerling in 1969. After one year, the silver salmon displayed greater survival and growth than the established red salmon (see Table 8). Growth and survival differences in the other study waters undoubtedly resulted from diverse environments and stocking densities. Fish mortality has also influenced the transplants. Upper Jean, Portage, and Sunken Island lakes have developed into popular winter sport fisheries.

TABLE 13 Relative Catch and Growth Rates for Red Salmon in Six Kenai Peninsula Lakes, 1969 and 1970.

Lake	Year Sampled	No. Fish	Length (mm) Range	Length (mm) Mean	Mean Weight (Lbs.)	Catch/ Net Hr.
Upper Jean	1969	183	168-312	179.7	0.14	3.27
	1970	11	184-215	200.5	0.19	0.14
Portage	1969	97	210-305	229.0	0.27	2.38
	1970	141	222-294	245.0	0.36	3.03
Sunken Island	1969	75	228-328	248.4	0.39	0.81
	1970	29	277-326	297.6	0.73	0.45
Bernice	1969	19	220-368	282.4	0.67	0.26
	1970	4	278-357	325.0	1.07	0.04
Bottinentin	1969	26	205-280	233.2	0.36	0.24
	1970	27	247-343	298.2	0.83	0.42
Island	1970	57	124-337	231.5	0.36	0.66

The percentage of sexually mature salmon varied considerably within the study lakes. Age V+ males comprised virtually the entire spawning population in most lakes; however, a substantial number of gravid females were present in Portage Lake (Table 14). The high percentage of immature fish indicates that many transplanted fish will have a greater life span than their parents. Anadromous red salmon return to Bear Creek in their fourth or fifth year of life.

TABLE 14 Sexual Maturity of Red Salmon in Six Kenai Peninsula Lakes.

Lake	Year Sampled	Sample Size	No. Mature Salmon Male	Female	Mean Length Mature Fish (mm)	% Mature
Upper Jean	1967	39	10	0	253.3	25.6
	1968	21	0	0	--	--
	1969	183	2	1	259.3	1.6
	1970	11	5	0	203.4	4.5
Portage	1967	33	0	0	--	--
	1968	43	2	1	246.0	7.0
	1969	97	38	0	230.6	39.2
	1970	141	71	21	244.7	66.0
Sunken Island	1967	144	1	0	278.0	0.9
	1968	38	4	0	229.2	10.5
	1969	75	13	1	258.5	18.7
	1970	29	5	2	291.0	24.1
Bernice	1967	10	0	0	--	--
	1968			No sample		
	1969	19	1	0	294.0	5.0
	1970	4	0	0	--	--
Bottinentin	1968	11	1	0	174.0	9.1
	1969	26	2	0	251.0	7.7
	1970	27	8	0	306.6	29.6
Island	1969			No sample		
	1970	57	5	0	242.0	8.8

Arctic Grayling:

Arctic grayling, Thymallus arcticus, which are not indigenous to the Kenai Peninsula, were introduced into Crescent Lake in 1952. A substantial, self-sustaining population developed rapidly from the initial plant of 240 adults. Since 1962, Crescent Lake has served as a donor for grayling transplants to other Kenai Peninsula waters.

Four grayling transplants were evaluated by gill net in 1970. Predominately age I and age II grayling from Crescent Lake were introduced into Bench, Grayling, and Upper Paradise lakes and hatchery fry were planted in South Fuller Lake. The grayling in Lower Paradise Lake are the result of egress from the successful Upper Paradise Lake transplant. Table 15 shows the numbers of fish and the dates introductions were made.

TABLE 15 Numbers of Arctic Grayling in Kenai Peninsula Lakes.

Lake	Year Planted	No. Fish
Upper Paradise	1962	242*
	1963	165
Grayling	1964	154
	1965	151
Bench	1967	240
South Fuller	1967	25,000**

*Mortality estimated to be 27%.
**Fry originated from an egg take at Bessie Creek located near Tolsona Lake, Glennallen.

With the exception of threespine stickleback in Grayling Lake, no endemic fishes reside in the recipient waters. Gill-net catches and shoreline surveys indicate natural reproduction in each of the lakes. Gill-net sampling results are presented in Table 16.

TABLE 16 Lengths, Weights, and Catch Per Gill-Net Hour for Transplanted Arctic Grayling, 1970.

Lake	No. Fish	Length (mm) Range	Length (mm) Mean	Mean Weight (Lbs.)	Catch/ Net Hr.
Lower Paradise	129	125 - 390	305.2	0.67	2.83
Grayling	91	115 - 320	196.5	0.20	1.98
Bench	30	115 - 365	135.3	0.09	0.65
South Fuller	10	296 - 339	317.5	0.86	0.20

Lake Trout Transplant:

A total of 204 lake trout, *S. namaycush*, were introduced into Upper Summit Lake in 1969 after studies suggested favorable conditions for establishing a self-sustaining population. In 1970, a supplemental transplant was attempted, utilizing lake trout from Skilak Lake.

Lake trout were captured by gill nets from September 29 through October 1 and from October 10 through October 14. The project was hampered during this period by adverse weather, equipment failure, and a scarcity of fish. Areas that yielded productive catches in 1969 produced poor catches in 1970. Gill net and holding mortalities were high because of severe wind and wave action. Only 12 lake trout were released into Upper Summit Lake before a heavy snowfall curtailed the project on October 15.

Miscellaneous Studies

Musick and Stickleback lakes were selected for further research on rainbow trout-threespine stickleback relationships. Separated by a low narrow neck of land, the two lakes have similar chemical, physical, and biological characteristics. A sand and gravel barrier was erected between the lakes to prevent interchange of fish during high water.

Musick Lake was treated with rotenone on September 15 to eliminate threespine stickleback. Both lakes will be stocked at equal fingerling rainbow trout densities during the spring, 1971. Survival and growth will be compared during succeeding years.

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